EO-Driven Digital Twin Ice Sheets

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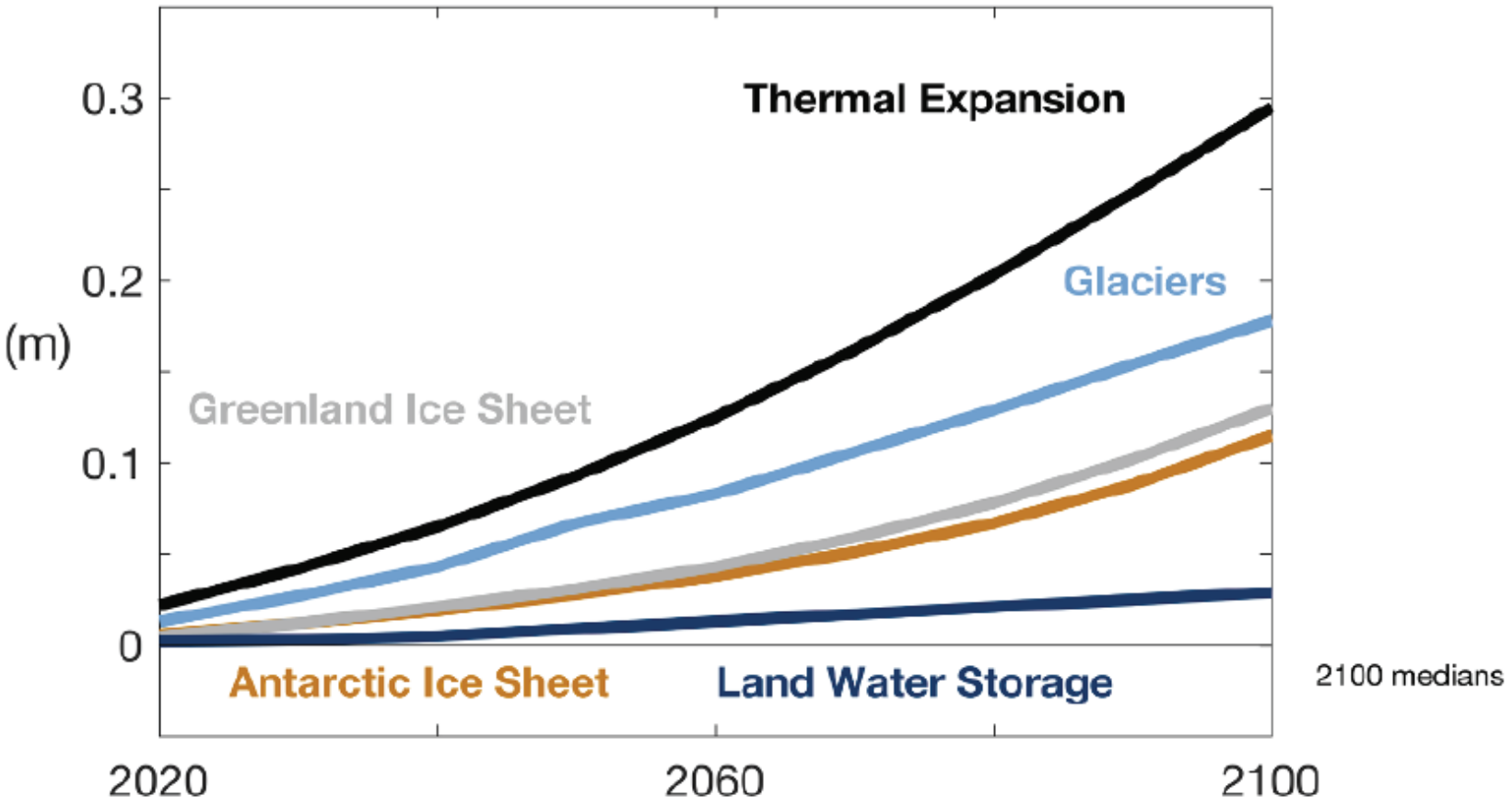
What happens in ...
stays in ...
WELCOME
TO Fabulous
Antarctica &
Greenland

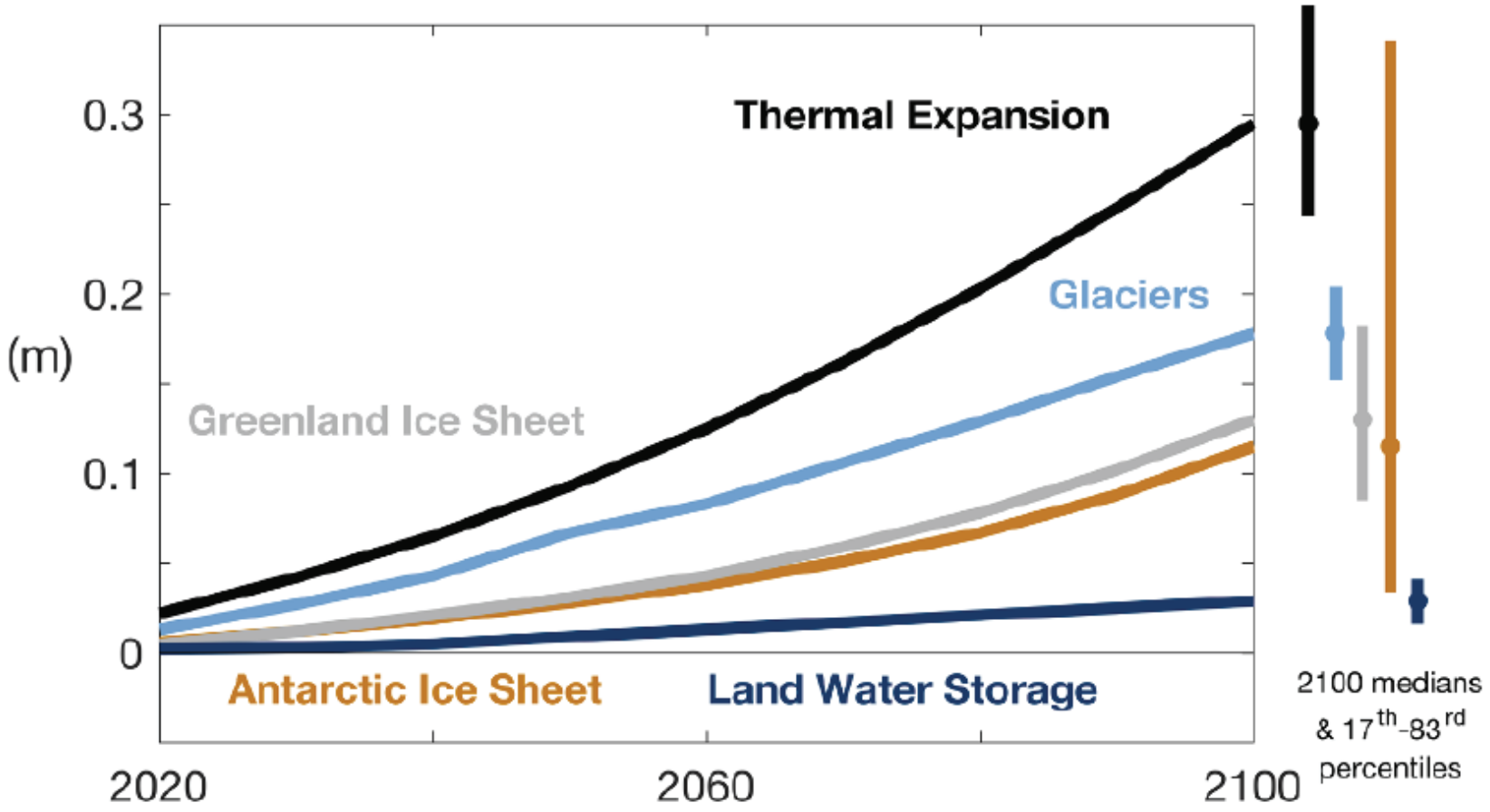

What happens in
does not stays in
WELCOME
TO Fabulous
Antarctica &
Greenland

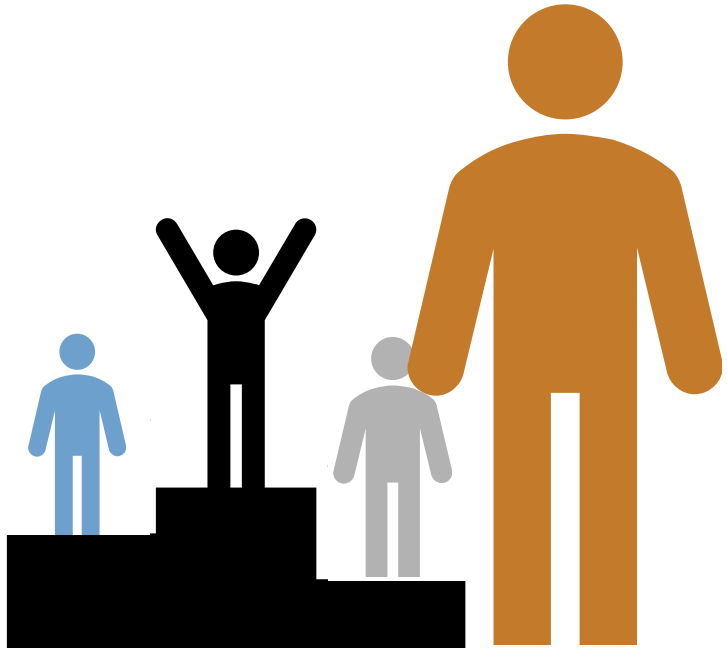
Why should we care?



IPCC AR6

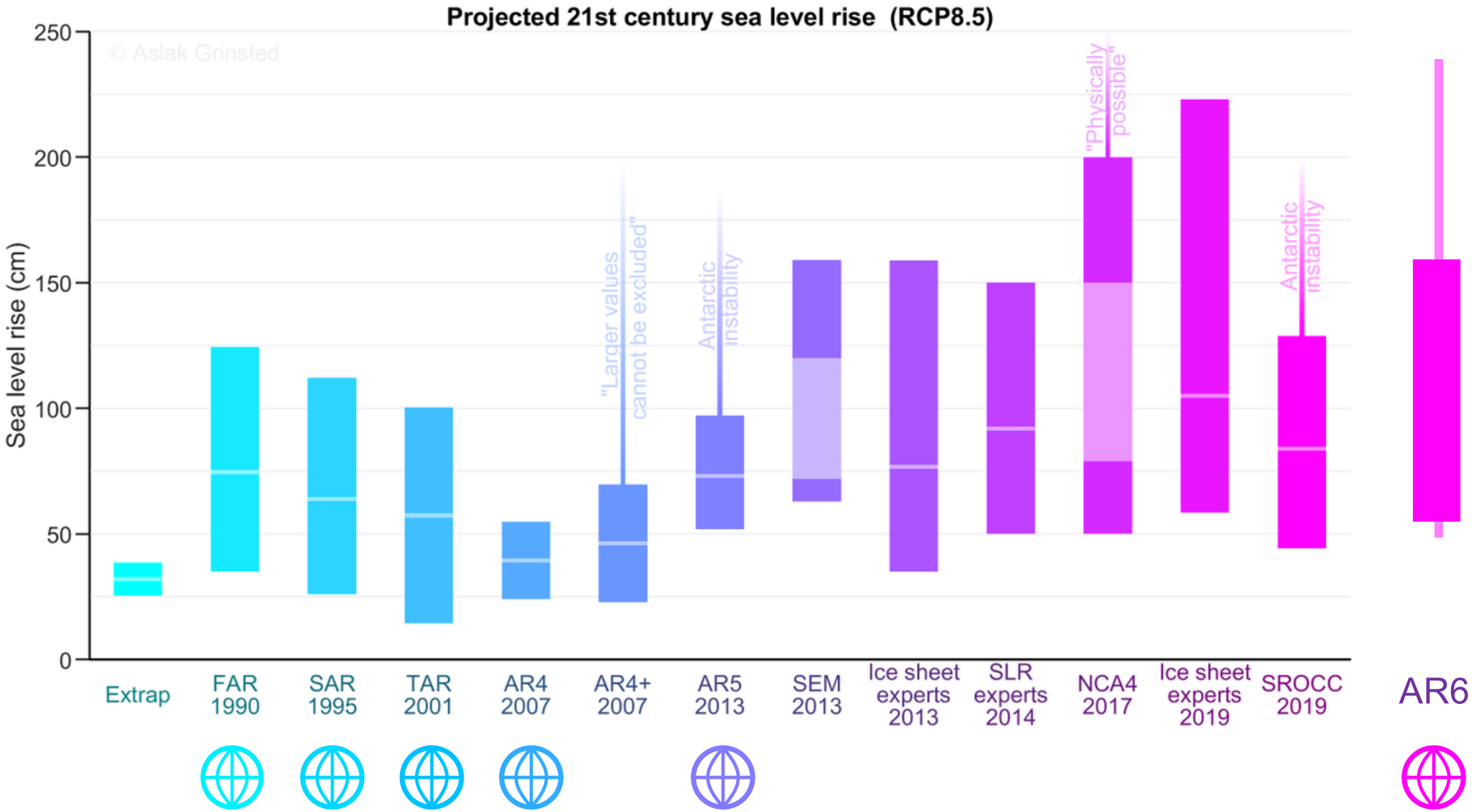
Both ice sheet have huge uncertainty





IPCC AR6

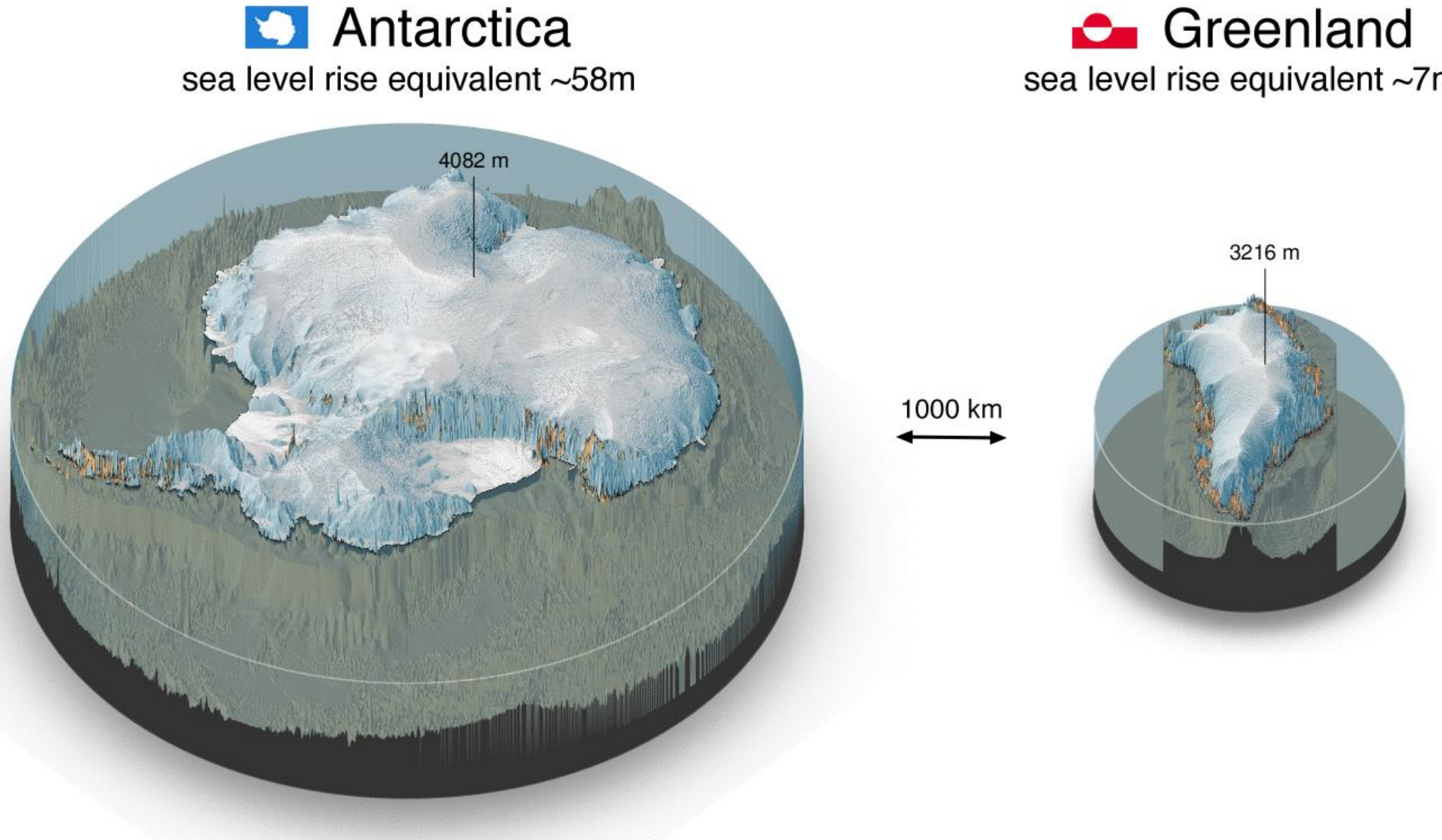
Uncertainty increases



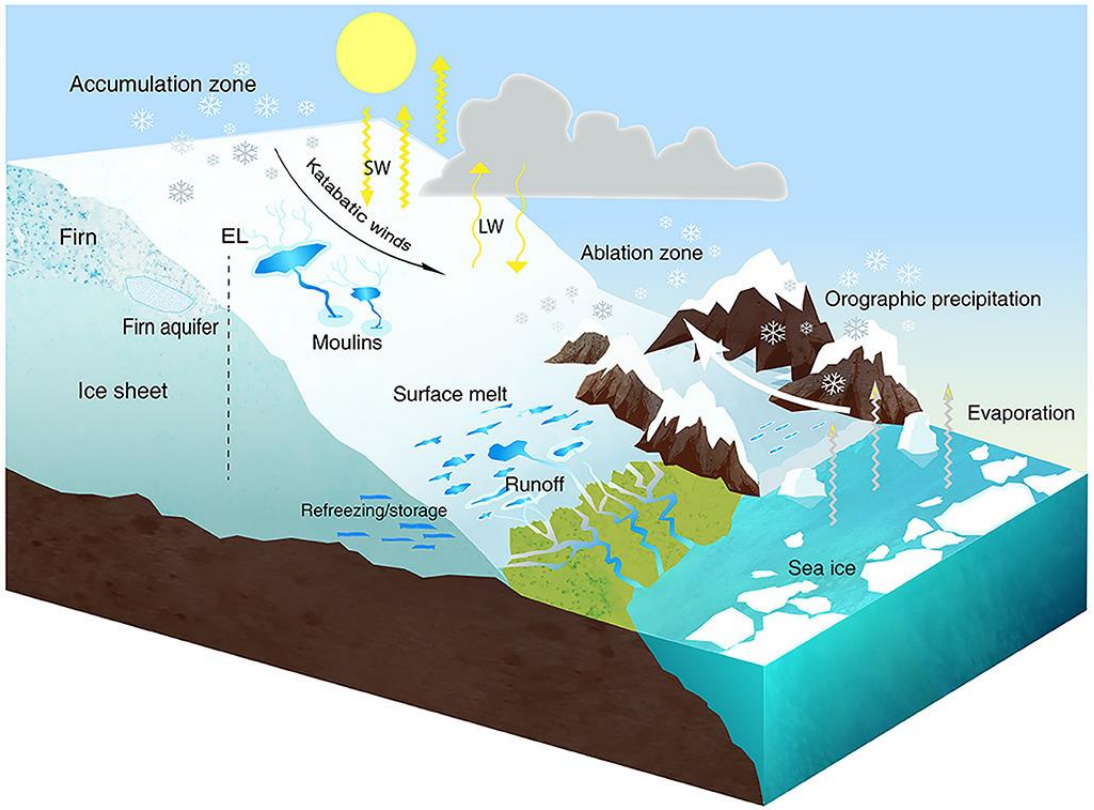
Antarctic instability

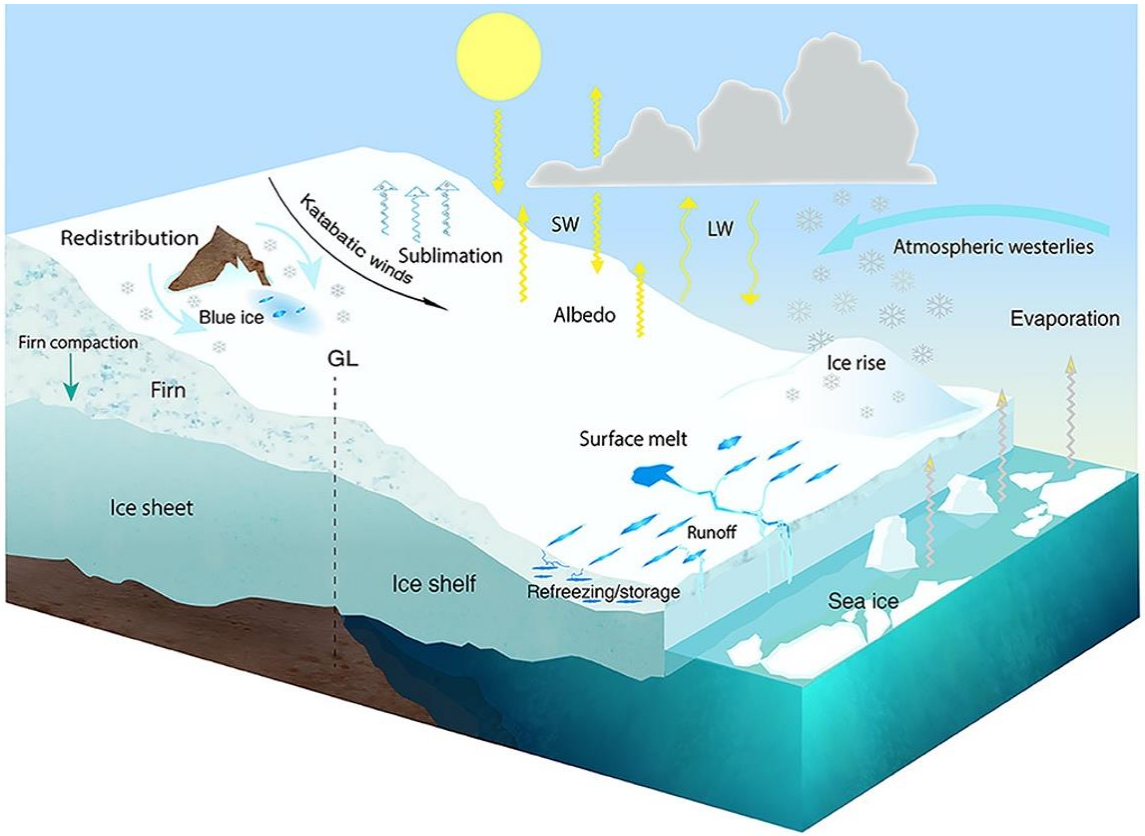
Grinsted 2019

Different ice sheets = different processes



Greenland melts at the surface, Antarctica at the edges



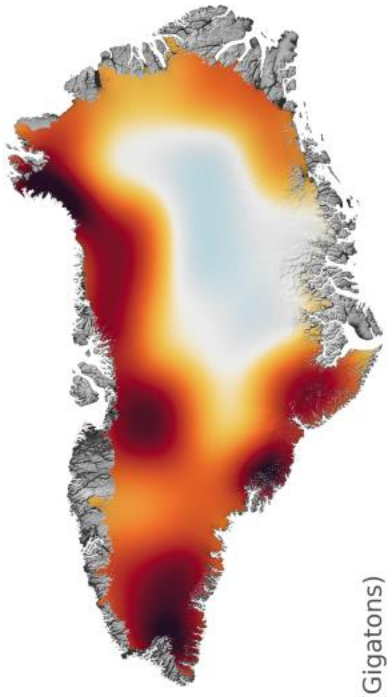


Lenaerts et al., 2019

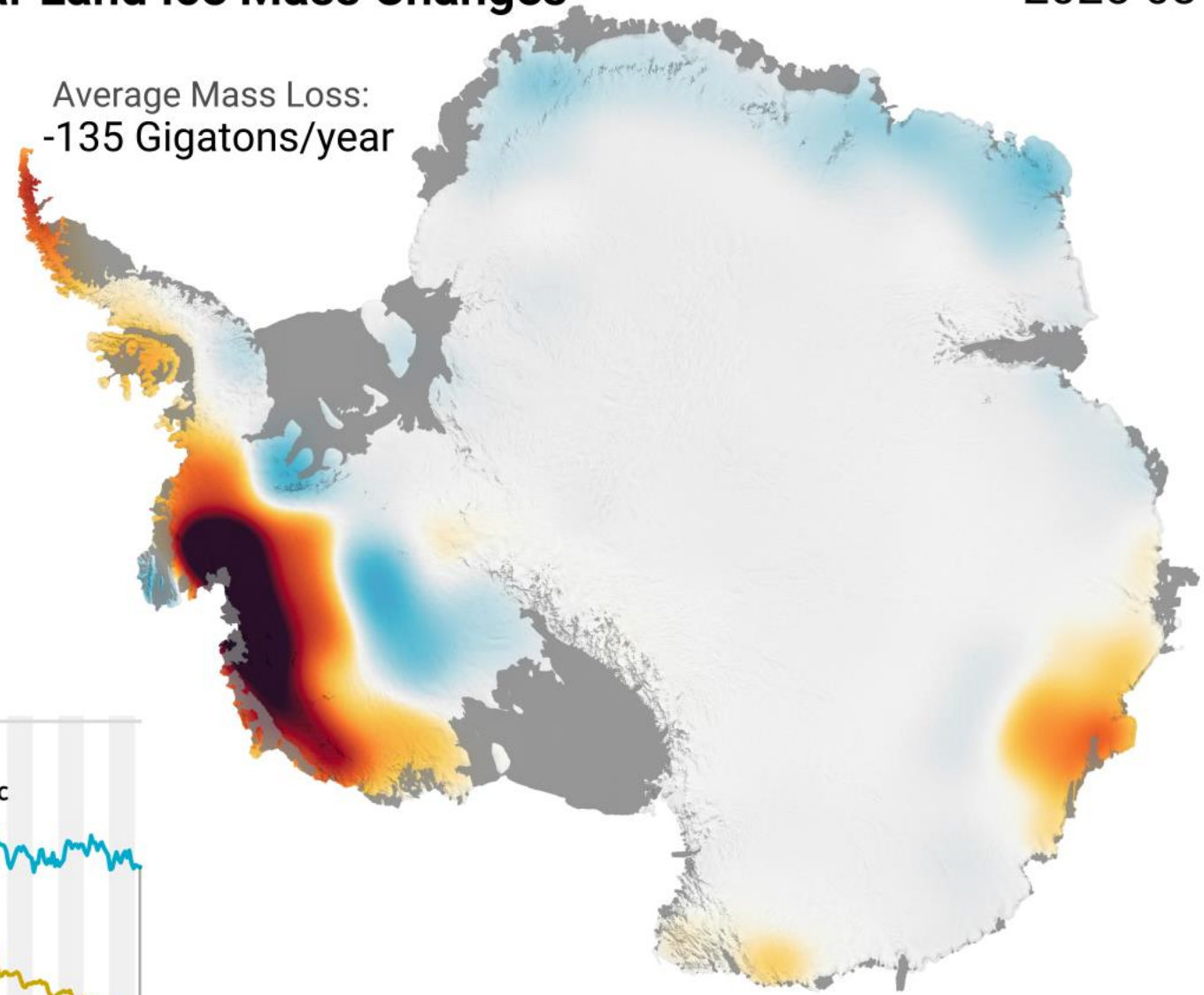
GRACE AND GRACE-FO Observations OF Polar Land Ice Mass Changes

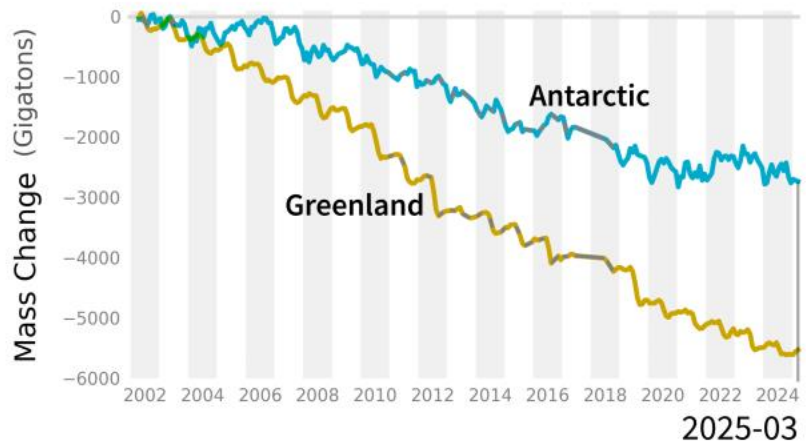
2025-03

Average Mass Loss:
-264 Gigatons/year



Average Mass Loss:
-135 Gigatons/year





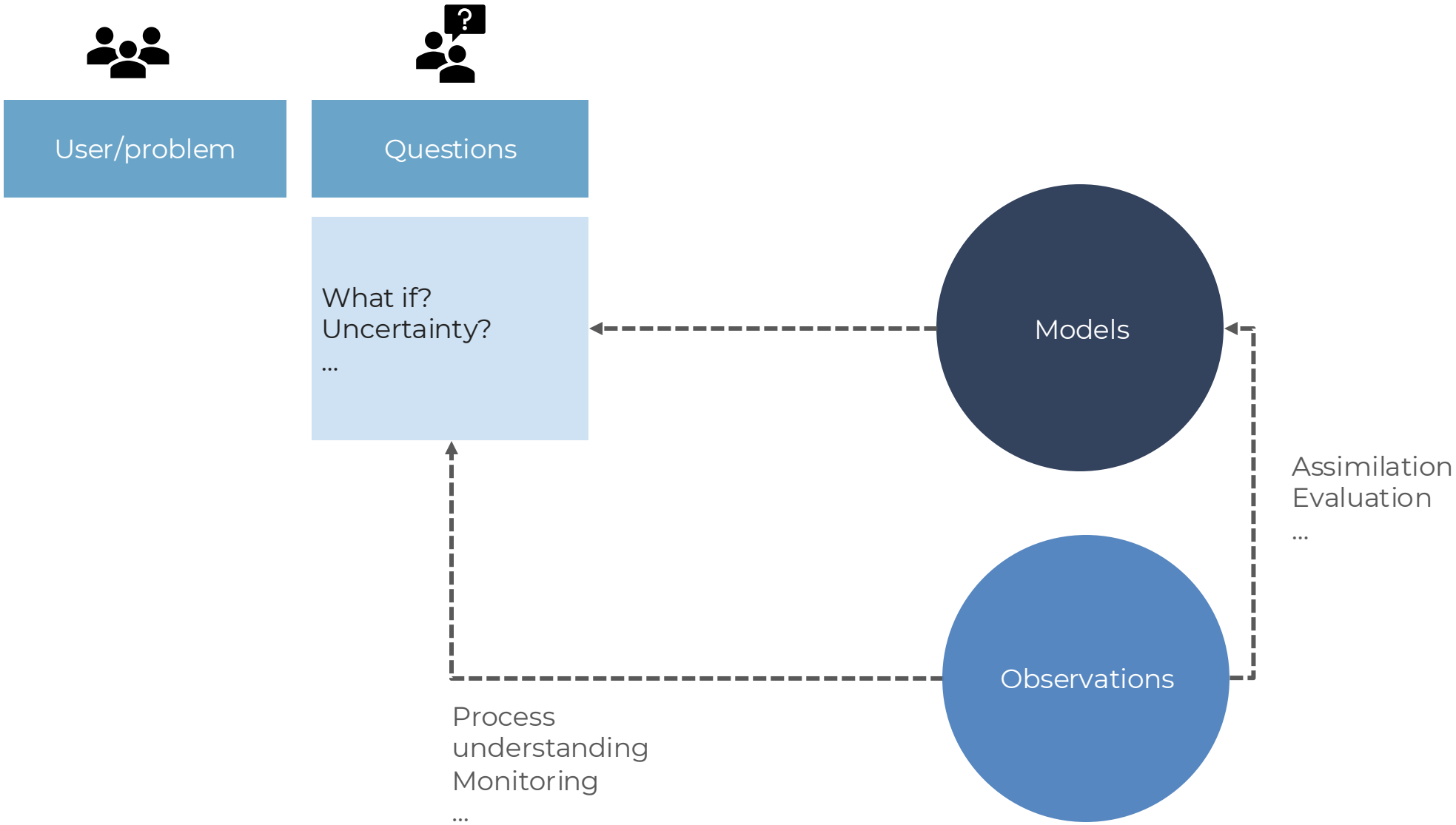
2025-03

Ice Mass Change
(meters water equivalent relative to 2002)

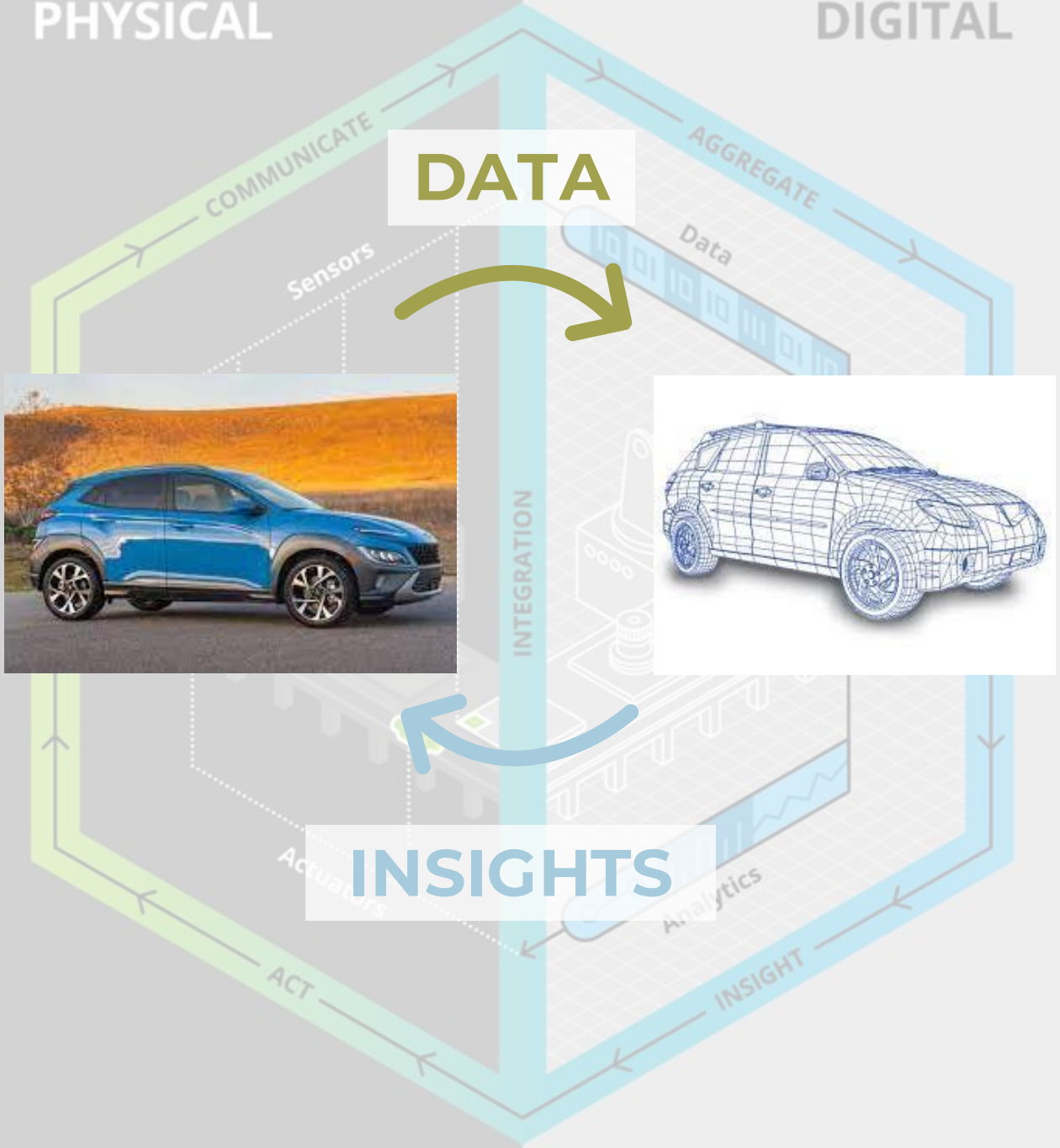
-6 -4 -2 0 2


policymakers
industry
public
scientists
Stakeholders

Digital Twins



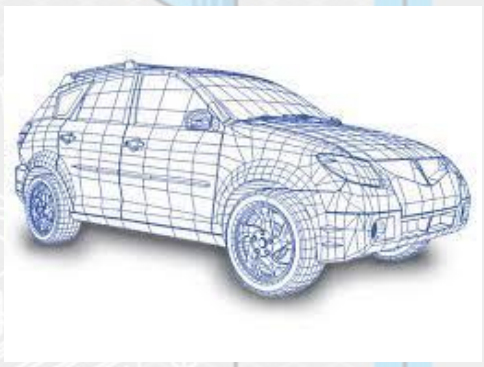
Digital Twin in industry



PHYSICAL

DIGITAL

DATA



INSIGHTS

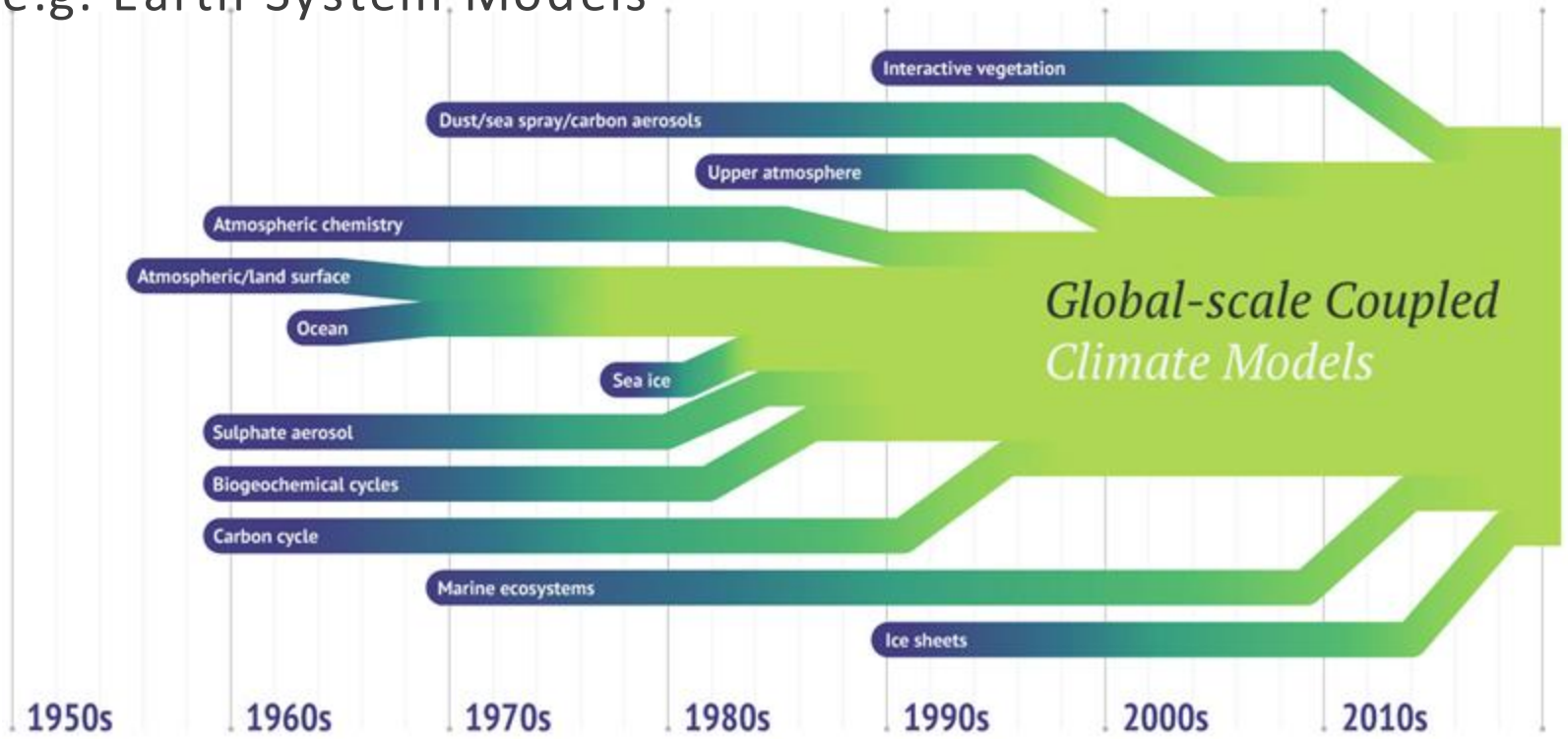
Digital Twins of

Still imperfect representations

Still too simplistic or
Computationally heavy

DIGITAL TWINS AS THE SOLUTION?

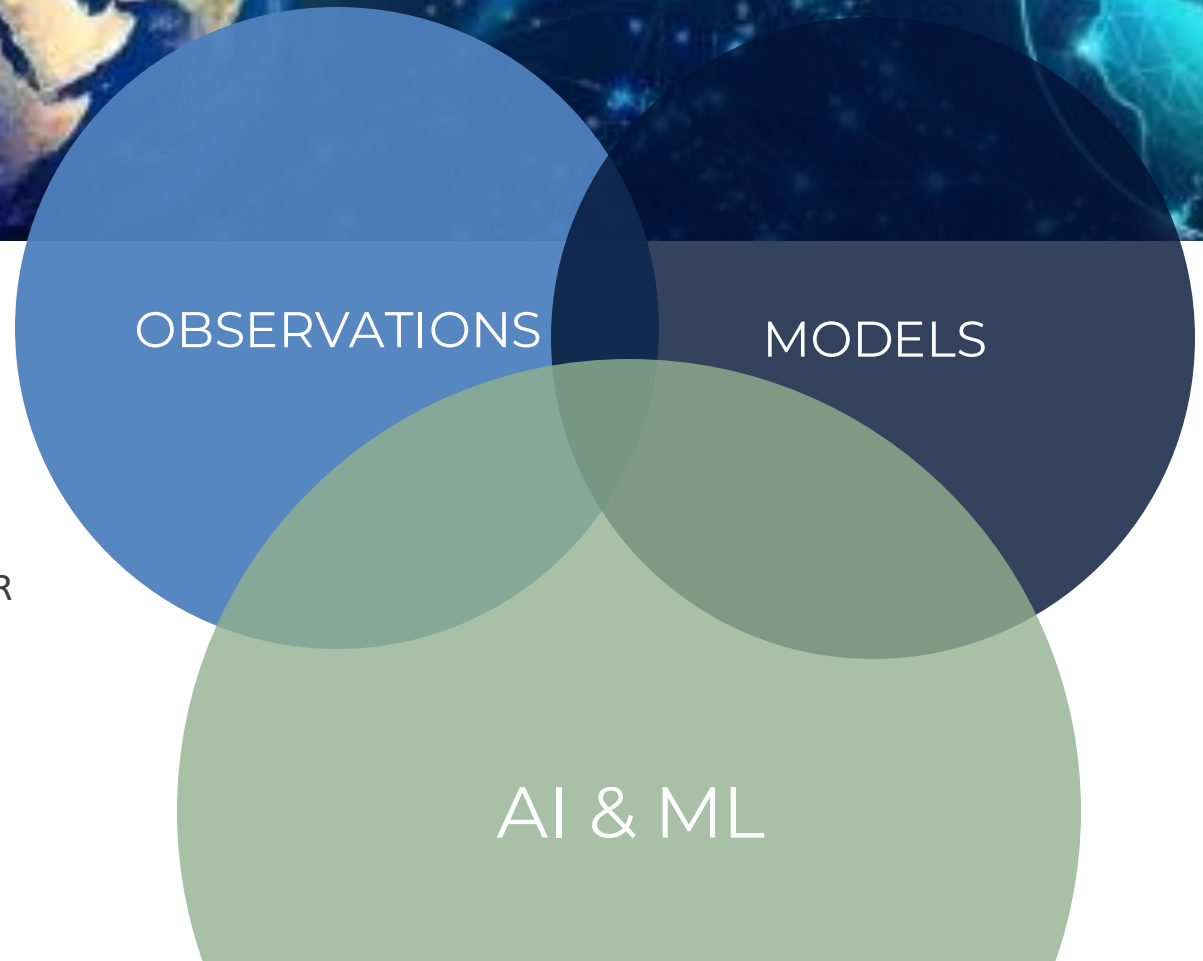
THEY ALREADY EXIST
e.g. Earth System Models




So what is new?

Digital Twin Innovations

- COMBINATION OF DATA LAKE WITH MODELS
- LEVERAGING THE POWER OF AI



AI brings new opportunities

Improved EO representations
Real time updates

AI simulations for speed-up,
Improved resolution

Monitoring, forecasting and scenario analysis

Welcome to DTC Ice Sheets

Welcome to the Digital Twin Component for Ice Sheets (DTC-IS), an ESA funded eo-driven digital twin. This digital twin integrates Earth Observation, in-situ data, re-analysis products, and advanced data-driven models to provide a dynamic and science-based representation of the Greenland and Antarctic ice sheets, including their ice shelves.

DTC-IS supports the monitoring, understanding, and prediction of ice-sheet change and its interactions with the climate system, enabling consistent assessment of impacts and uncertainties across local to global scales. By combining observations and models within a unified Digital Twin framework, it delivers actionable information for research, policy, and scenario-based exploration.

Use this dashboard to explore the current state of the ice sheets, examine past and ongoing changes, and assess possible future trajectories. For advanced users and researchers, interactive Jupyter notebooks and GitHub repositories are available in each tab, enabling you to work with your own implementations and build custom use cases from the DTC-IS framework.

dtc-ice-sheets.org

Stakeholders

4 use cases

Ice Sheets

State and Mass Balance

Synoptic view of ice-sheet state variables and mass balance indicators. Supports interactive sensitivity and what-if experiments.

Ice Shelves

Monitoring of State and Fate

Up-to-date reconstructions of Antarctic ice-shelf state and evolution, with access to underlying EO, in-situ, and re-analysis datasets.

Surface Climate & Hydrology

Enhanced Surface Knowledge

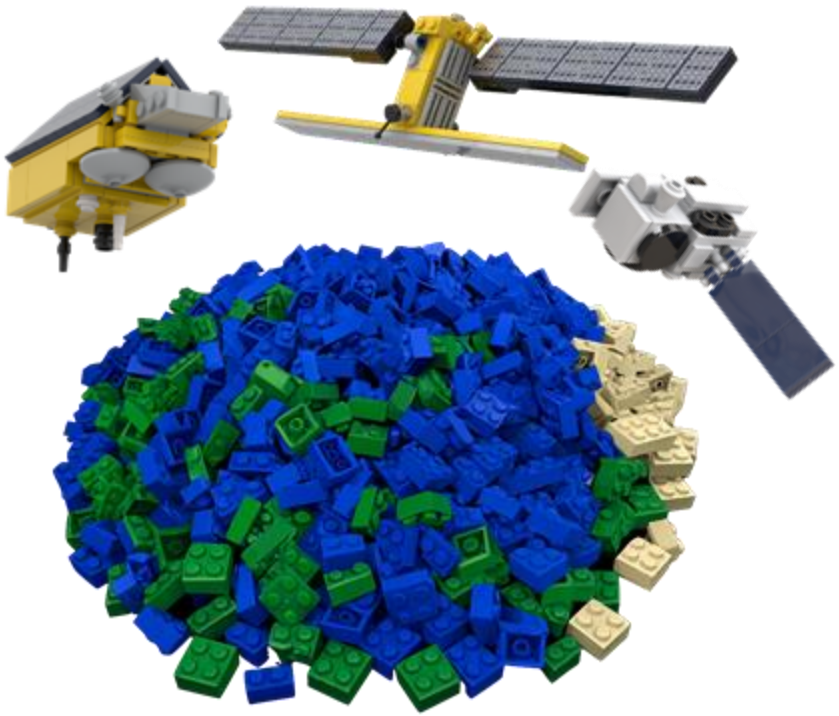
Super-resolution downscaling improves surface climate representation and freshwater runoff relevant to hydrology and hydropower.

Sea-Level Response

Global Fingerprint of Impact

Contribution of ice-sheet change to global and regional sea-level rise, supporting impact assessments and risk analysis.

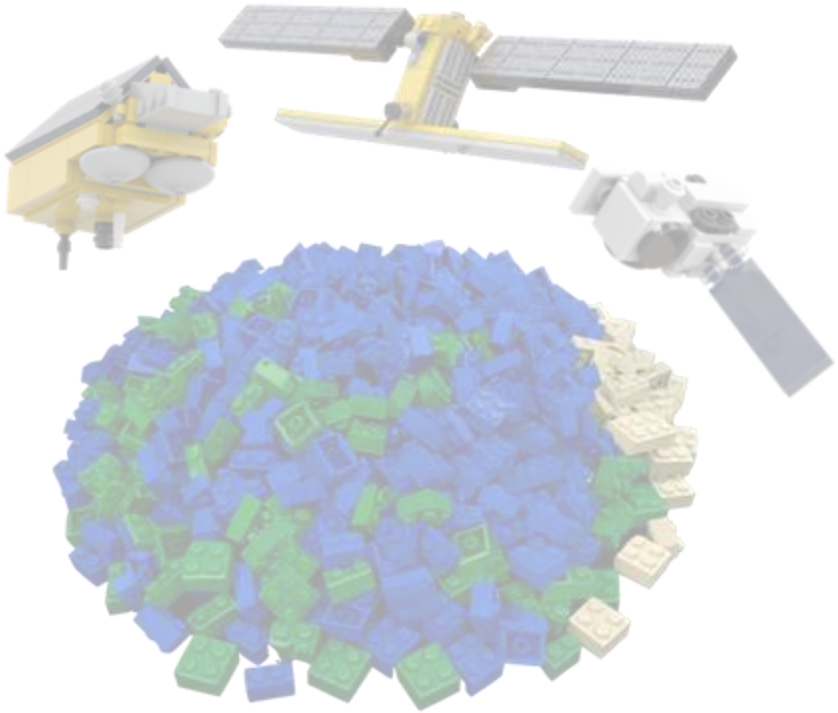
From building blocks



The Building Blocks

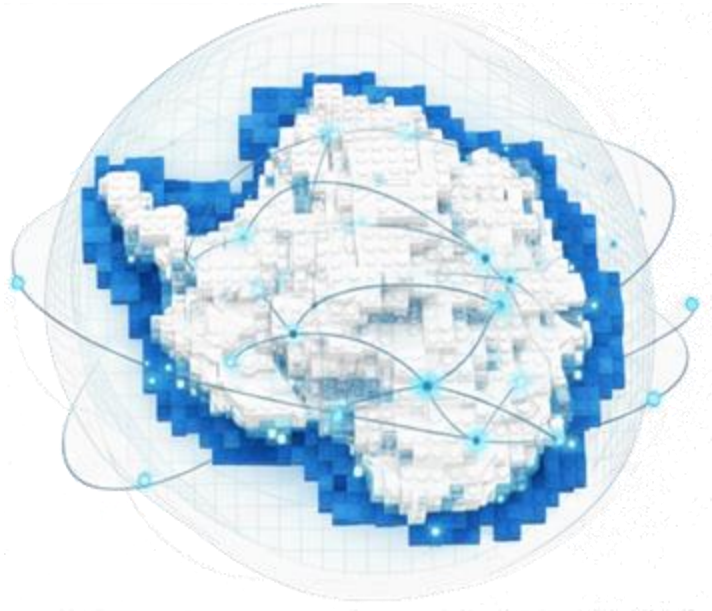
EO, In-situ data & algorithms.

to an ice sheet component



The Building Blocks

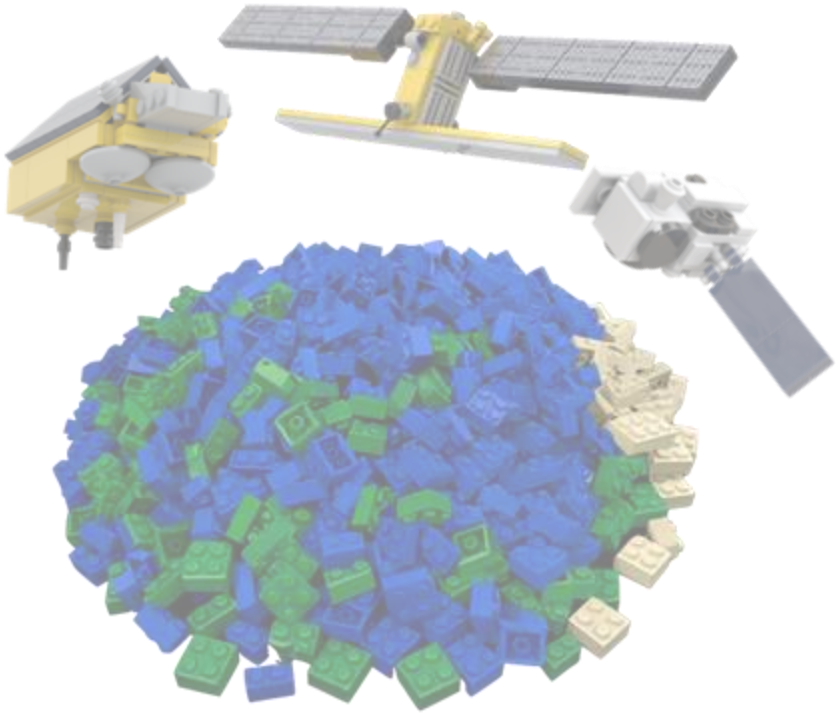
EO, In-situ data & algorithms.



The Component

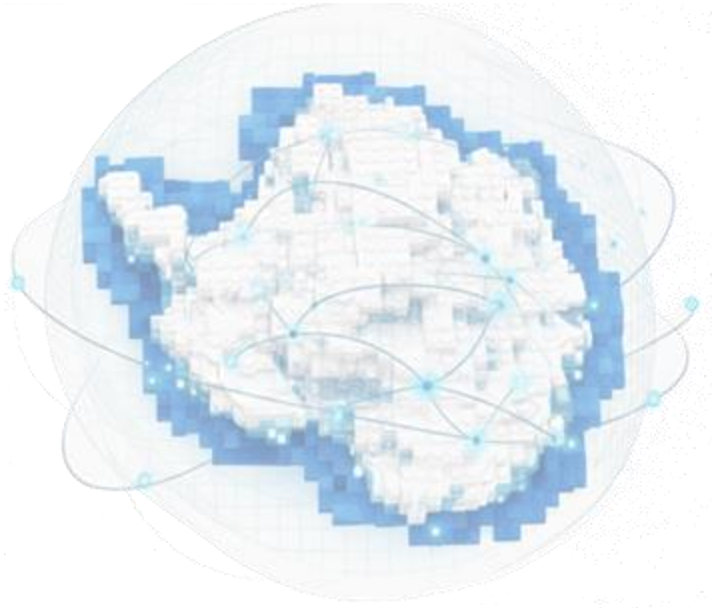
A specialized Ice Sheet Replica.

to an ecosystem of ecosystems



The Building Blocks

EO, In-situ data & algorithms.



The Component

A specialized Ice Sheet Replica.

The Ecosystem

Integrated into the full Digital Twin Earth.

Under the hood?

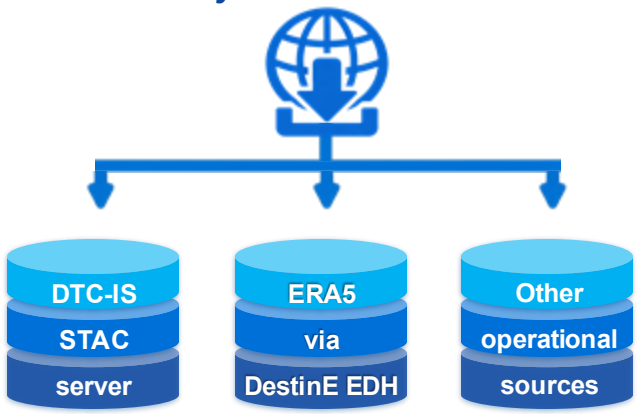
Modules & Workflows

Containerised & Orchestrated
Standardised I/O schemas

Publishable to DeltaTwin & Insula Processing
Compatible with internal DestinE infrastructure

Data Layer

Abstracted data access
On-the-fly GeoZarr conversion



Extensible to other DestinE data access APIs
Internal STAC potentially publishable to DEDL

API & Access

Unified external API
Decoupled dashboards & notebooks

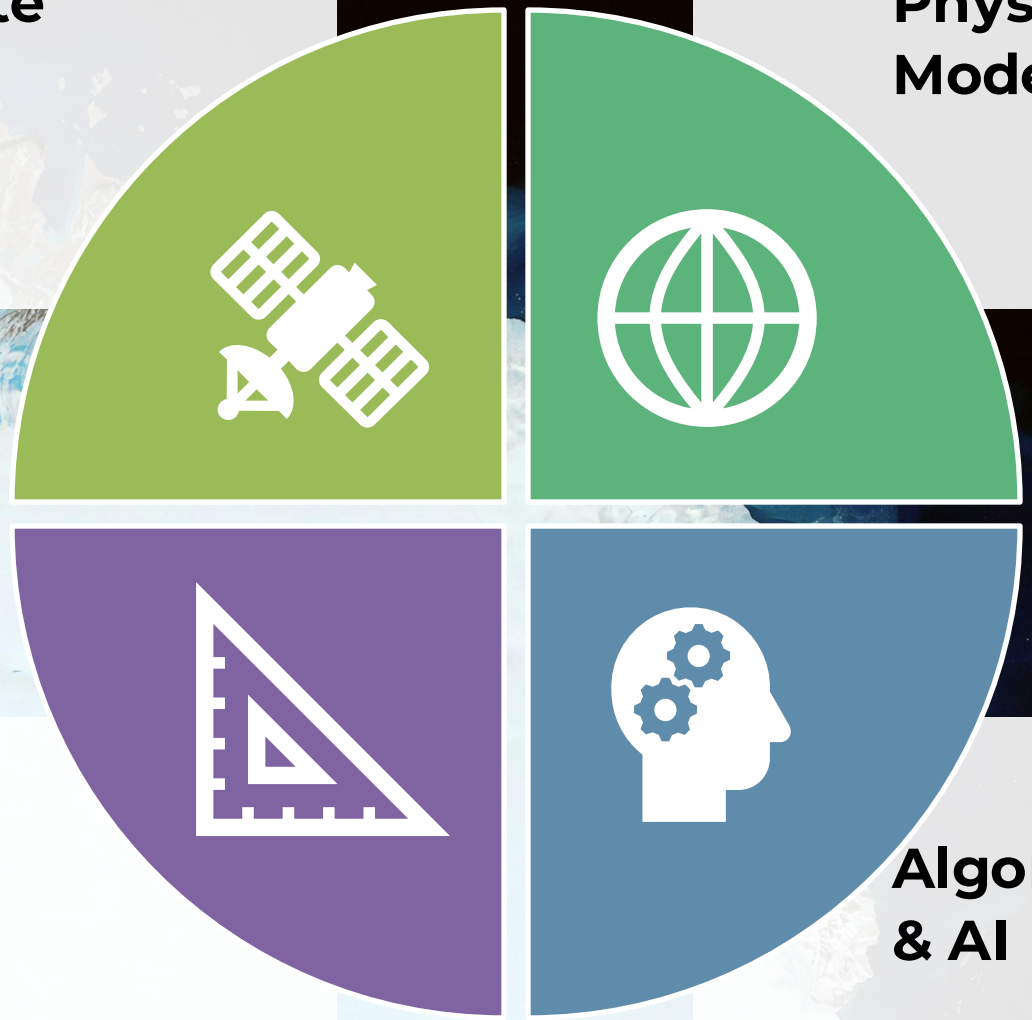
Notebooks to be published in Insula Code
Dashboard onboardable as DestinE service

Cloud-Native, Flexible & Portable Across Platforms

Poetry argo STAC Zarr FastAPI

Satellite data

Physical Models



In-situ data

Algorithms & AI

AI opportunities

Monitoring → **Understanding** → **Projection Scenarios**

Gap filling

Super-resolution

Classification & segmentation

Object detection & change/anomaly

AI opportunities

Monitoring → **Understanding** → **Projection Scenarios**

Gap filling

Geospatial foundation models

Super-resolution

Classification & segmentation

Interpretability & process discovery

Object detection & change/anomaly

EO–model diagnostics

AI opportunities

Monitoring → **Understanding** → **Projection Scenarios**

Gap filling

Super-resolution

Classification & segmentation

Object detection & change/anomaly

Geospatial foundation models

Interpretability & process discovery

EO–model diagnostics

What-if?

Model emulation Fast surrogates

Hybrid forecasting (physics + ML)

GenAI

AI opportunities in DTC ice sheets

Current modules

What-if?

Super-resolution

Model emulation
Fast surrogates

Interpretability &
process discovery

EO–model
diagnostics

Super-resolution

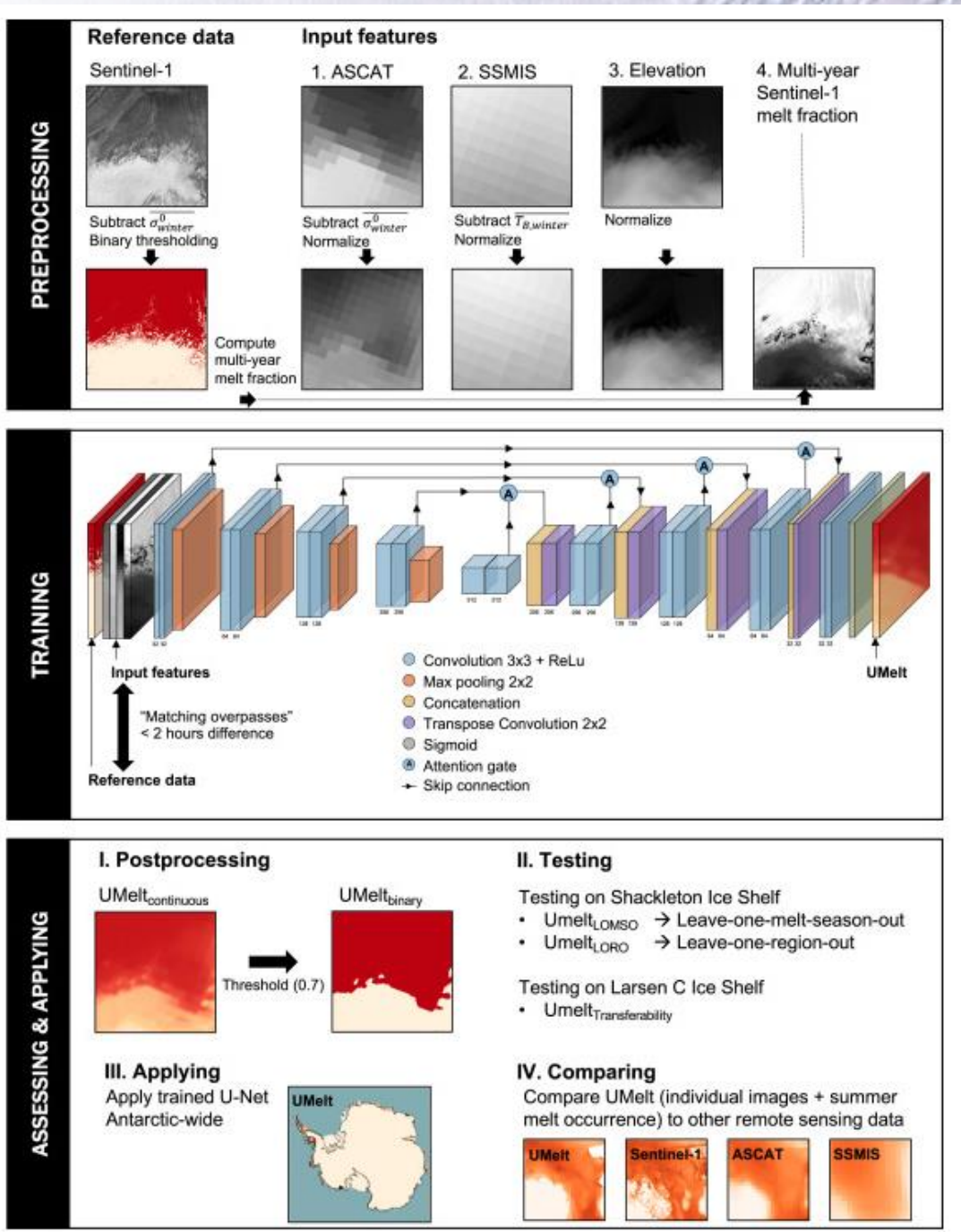
ELSEVIER

Remote Sensing of Environment

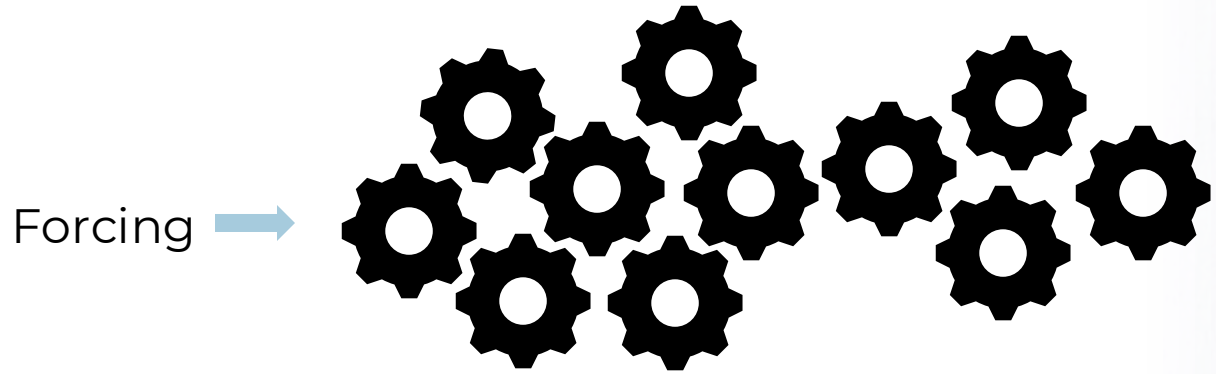
Volume 301, 1 February 2024, 113950

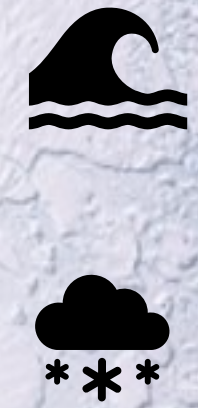
A high-resolution record of surface melt on Antarctic ice shelves using multi-source remote sensing data and deep learning

Sophie de Roda Husman [a], Stef Lhermitte [c a], Jordi Bolibar [a], Maaike Izeboud [a], Zhongyang Hu [b], Shashwat Shukla [a], Marijn van der Meer [d], David Long [e], Bert Wouters [a]



Development of emulators





Ice Sheet Mass Balance

Jupyter Notebook | GitHub Repo

Real-time predictions of Ice Sheet Mass Balance by a machine learning model trained on EU Copernicus Climate Change Service (C3S) data: ice velocity, land surface temperature, and radar elevation change.

Products matured from extensive R&D under the ESA Climate Change Initiative.

About the Model

Based on Simonsen et al. (2021) methodology converting ESA radar altimetry to mass balance.

Greenland

"What-If" Scenarios

Adjust parameters to explore climate impacts on ice sheet mass balance.

Ice Velocity (%)

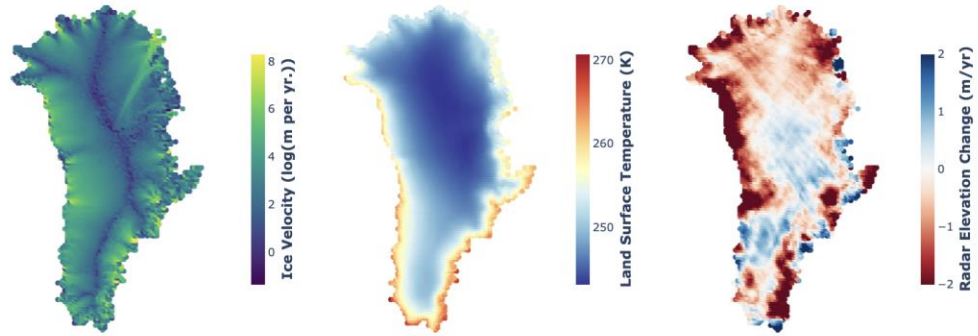
50% 100 150%

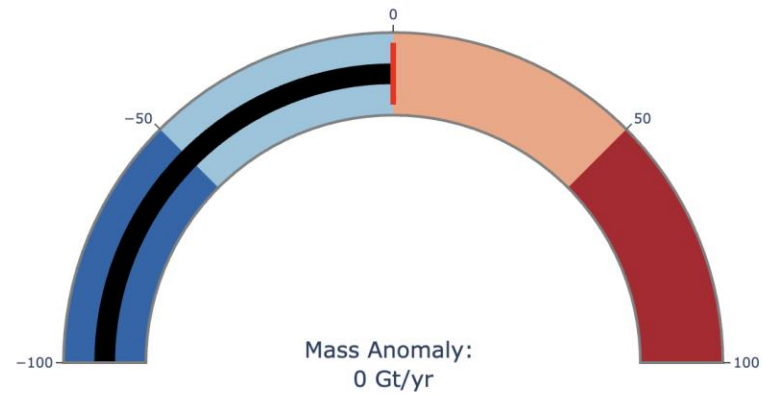
Temperature (K)

-10K 0 +10K

Radar Elevation (%)

50% 100 150%





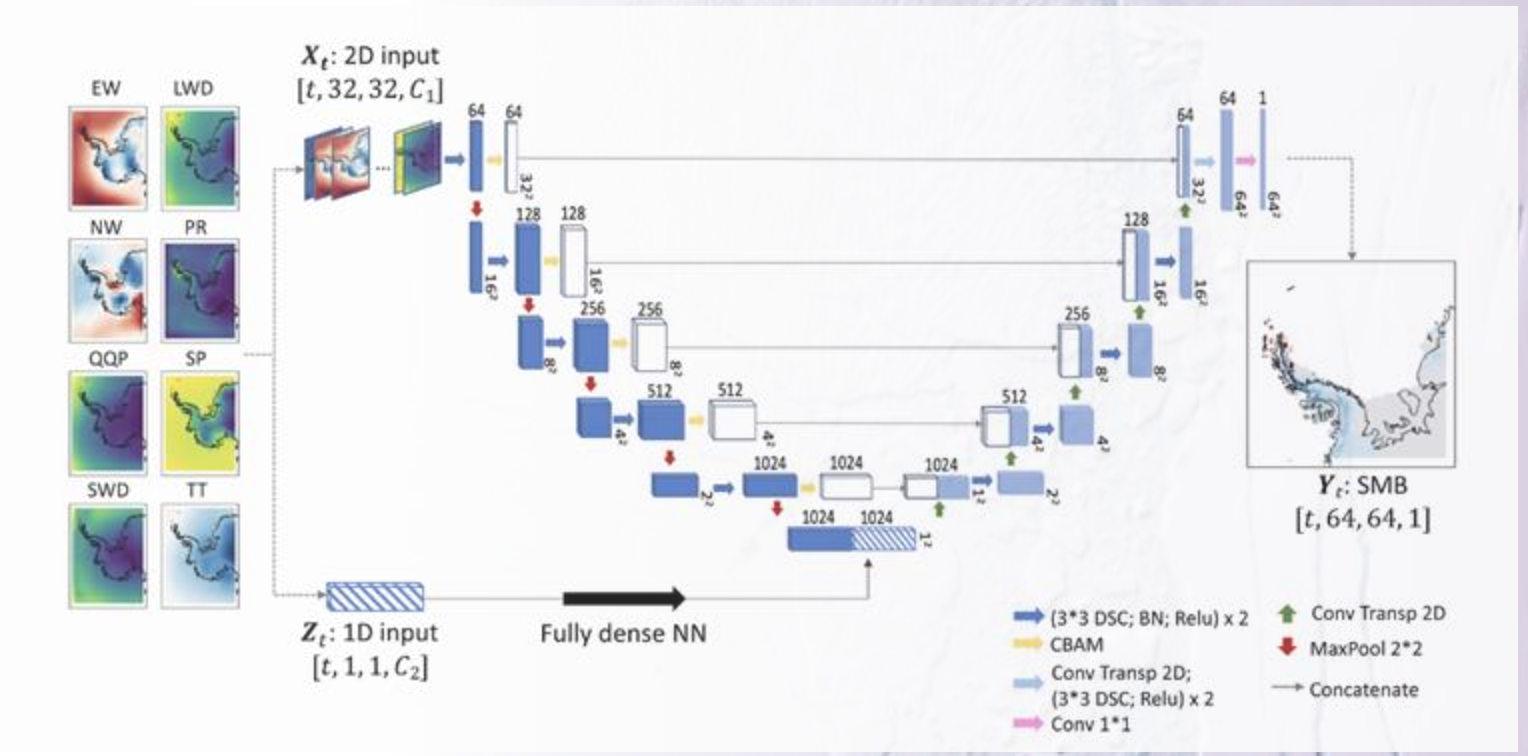
Emulators

JAMES | Journal of Advances in Modeling Earth Systems

Research Article | Open Access

Deep Learning Regional Climate Model Emulators: A Comparison of Two Downscaling Training Frameworks

Marijn van der Meer, Sophie de Roda Husman, Stef Lhermitte

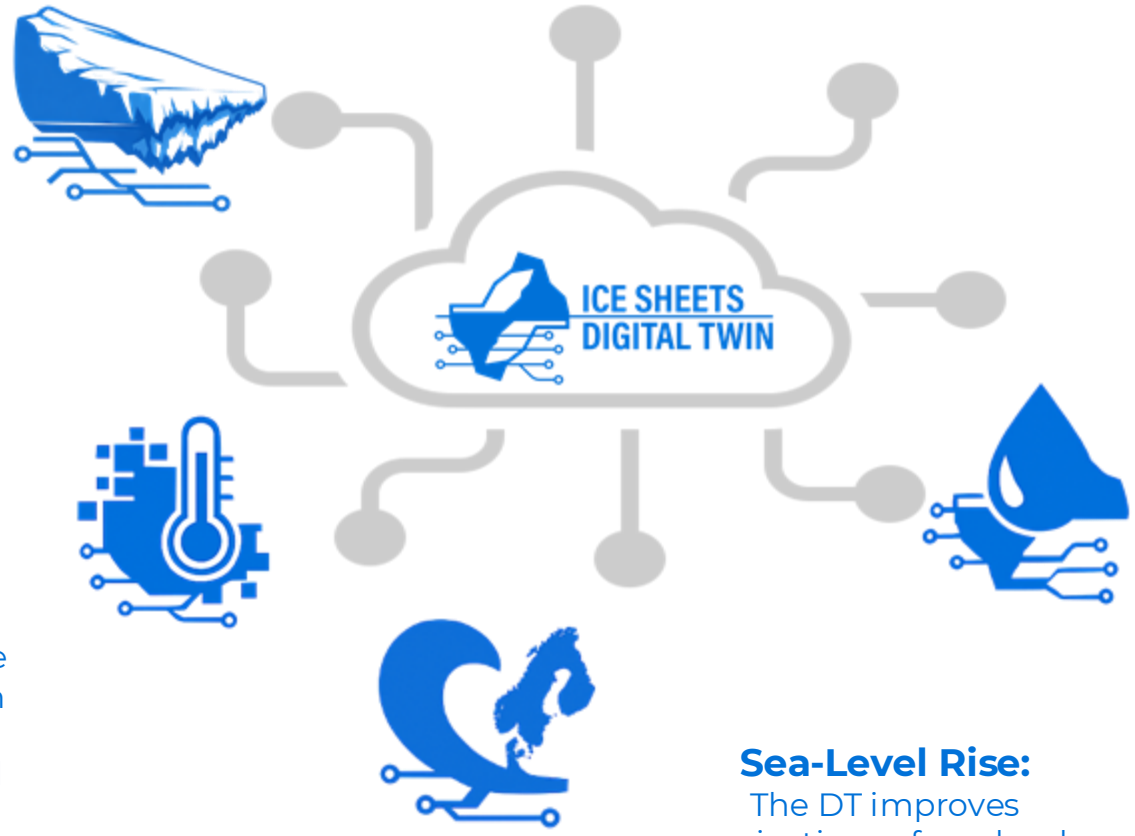


ICE SHEETS DIGITAL TWIN

dtc-ice-sheets.org

Antarctic Ice Shelves

The DT tracks ice-shelf change using satellite data and modeling to help assess risks and feedback between ice and ocean.



Enhanced Surface Climate

The DT leverages super-resolution modeling techniques to enhance the monitoring and prediction of surface climate conditions over Greenland and Antarctica.

Hydropower in Greenland:

The DT estimates meltwater runoff, enabling better forecasting of hydrological resources for renewable energy planning.

Sea-Level Rise:

The DT improves projections of sea-level changes driven by ice-sheet melt to support regional coastal planning across the EU.